Summaries from the meeting “International Update on Osteoarthritis of the Knee”

ROBERT W. JACKSON, MD

Aware that an orthopaedic surgeon, Dr. Adolph Lorenz, was the catalyst for the development of the Baylor Health Care System in 1903, the Department of Orthopaedic Surgery organized a major academic event to be part of Baylor's centennial celebration. The event, “International Update on Osteoarthritis of the Knee,” was held at the Four Seasons Resort in Las Colinas from June 12–14, 2003. The conference addressed one of the most common problems facing our population today, i.e., arthritis of the knee, and the faculty consisted of prominent international figures in the field of knee surgery, augmented by surgeons from Baylor's own staff. The course was widely advertised and attracted more than 150 registrants representing 8 different countries. The faculty did a marvelous job, and feedback after the meeting was that “this was the best knee course ever!” The sessions from the meeting are summarized below.

SESSION 1—CLINICAL AND RADIOLOGICAL ASSESSMENT

► Dr. Robert Bourne, Professor of Surgery, University of Western Ontario, London, Canada

After reviewing the main details of *clinical examination*, Dr. Bourne emphasized the use of outcome tools such as the WOMAC osteoarthritis index and the SF-36 general function questionnaire to quantify disability and treatment results. He discussed the cost/benefit analysis of orthopaedic procedures that improve quality of life compared with procedures that are directed toward maintaining life. For example, approximately \$6000 will pay for a total knee replacement and produce a functional individual. In contrast, \$70,000 or so is required to keep someone on hemodialysis during the last few months of life. Unfortunately, the government and insurance companies have not yet realized that quality of life should be supported as well as quantity of life.

► Dr. Vladimir Bobic, Consultant Knee Surgeon, Chester, United Kingdom

Dr. Bobic spoke about *advances in magnetic resonance imaging*, explaining the high-resolution volumetric cartilage studies that are available, as well as the 3-dimensional visualization of articular surfaces. New techniques can also show the glycosaminoglycan content of articular cartilage. Tremendous work is being done in this area.

SESSION 2—NONSURGICAL MANAGEMENT

► Dr. Fabian Pollo, Biomedical Engineer, Director of Orthopaedic Research, Baylor University Medical Center, Dallas, Texas

Dr. Pollo discussed the use of the *unloader brace* for medial compartment osteoarthritis. Normally during walking, weight-bearing and muscle forces are transmitted primarily through the medial compartment of the joint, thus producing a varus moment. An unloader brace tends to reduce the load on the medial compartment by approximately 17% if an 8° of valgus is built into the brace. Clinical studies also show an improvement in symptoms, which is backed up by gait analysis. Recently, Dr. Anderson, in New Zealand, implanted pressure transducers into the medial compartment and showed a 68% reduction in medial loads when an unloader brace was applied.

► Dr. Wayne Marshall, Assistant Professor of Surgery, University of Toronto, Canada

Dr. Marshall described various *injectables and medications* for treating arthritis. Glucosamine and chondroitin sulfate have been shown to have an analgesic effect and may modify the disease. Nonsteroidal antiinflammatory drugs have a significant downside, as they cause approximately 16,500 deaths per year in the USA, mostly in elderly patients, due to gastrointestinal bleeding. The cyclooxygenase (COX)-2 inhibitors block the “bad” COX-2 and allow the “good” COX-1 to do its work; they have not been related to gastrointestinal bleeding. Cortical steroids have both proponents and critics, but large doses of cortical steroids are probably bad in the long term. Visco supplementation involves the injection of hyaluran and appears to be a good technique from a cost/benefit standpoint. In a well-controlled study in Canada, 38% improvement in patients was noted with Visco supplementation. Only 3% of patients had adverse reactions, and none died. Early evidence also suggests that these injections increase the activity of the synoviocytes that produce hyaluronic acid in the joint.

From the Department of Orthopaedic Surgery, Baylor University Medical Center, Dallas, Texas.

Corresponding author: Robert W. Jackson, MD, Department of Orthopaedic Surgery, Baylor University Medical Center, 3500 Gaston Avenue, Dallas, Texas 75246 (e-mail: rw.jackson@BaylorHealth.edu).

SESSION 3—MINIMALLY INVASIVE TREATMENT

- **Dr. Robert W. Jackson, Chief of Orthopaedic Surgery, Baylor University Medical Center, Dallas, Texas**

Dr. Jackson described his experience with *arthroscopic lavage and debridement* for osteoarthritic knees. In a recent 4- to 6-year study, he classified each case into one of 4 stages (IV being the worst), depending on clinical symptoms, physical signs, x-ray findings, and confirmation with arthroscopic appearance. The results of lavage and debridement, when analyzed according to the severity or stage of the degenerative process, clearly showed that in the early stages (stages I and II), excellent results could be obtained. In stage IV, there were no excellent results and 12% good, 52% fair, and 35% poor results. Stage III cases were improved to some degree, with almost 50% having excellent or good results and another 25% having fair results. This study did not include any of the biological resurfacing cases that were done; therefore, it is a baseline to which efforts at biological resurfacing in stages III and IV can be compared.

- **Dr. James Tasto, Clinical Professor, University of California, San Diego, California**

Dr. Tasto stated that bipolar *radiofrequency arthroplasty* can be very useful, but there is no place for a monopolar unit. Radiofrequency chondroplasty, which produces heat, was contrasted with coblation chondroplasty, which has minimal heat production. Some investigators reported bad results that were due to improper use of the technique, including variables such as power settings, time of application, amount of pressure, and whether or not the wand was moved over the area or kept still. Different ways of determining cell death, or apoptosis, are being developed.

- **Dr. Lars Peterson, Professor of Orthopaedics, Gothenburg, Sweden**

Dr. Peterson discussed the arthroscopic treatment of *osteochochondritis dissecans* (OCD). Regardless of the treatment given (according to a large study done by Linguin in Sweden), 80% of patients with OCD will develop osteoarthritis after 20 years. The juvenile form of OCD with stable cartilage cover at arthroscopy can be treated conservatively. If the lesion is unstable but the cartilage is still relatively intact, Dr. Peterson recommends a retrograde type of drilling. If the cartilage is separated, the unstable fragment usually needs to be removed; unfortunately, if left untreated, 100% of these patients develop osteoarthritis within 30 years. If the fragment of bone and overlying cartilage must be removed, the defect should be treated by curettage of the base, osteochondral grafting, and pin fixation. If a loose body in the knee and an "empty nest" (i.e., the origin of the loose body) are present, the loose body should, if possible, be replaced. However, if there is bone loss and the loose body does not fit smoothly, it is probably better to debride the base, drill the subchondral bone, fill the defect with bone graft, cover it with fibrin glue, and consider covering the area later with the autologous chondrocyte transplantation technique.

SESSION 4—BIOLOGICAL RESURFACING

- **Dr. Richard Steadman, Clinical Professor, The University of Texas Southwestern Medical Center, and Orthopaedic Surgeon, Vail, Colorado**

Dr. Steadman described the major indication for the *microfracture technique*: a full-thickness defect in a stable joint. Contraindications included axial malalignment, cruciate instability, partial-thickness defects, and age >65 years. He emphasized that the microfracture technique involves not only the creation of small holes through the subchondral bone, leaving areas of supporting subchondral bone between each of the holes, but also the rehabilitation process that follows. He described a rehabilitation program that involves constant movement of the knee for approximately 8 hours a day on continuous passive movement (CPM) or many voluntary cycles if a CPM unit is unavailable. Partial weightbearing is recommended for 8 weeks, and after that, full weightbearing and the development of muscular strength is suggested.

For the surgical procedure, the lesion must be prepared with resection back to stable edges of articular cartilage and removal of the calcified cartilage layer in the base of the exposed area. Dr. Steadman reported a 92% improvement in patients if the microfracture technique is done appropriately. Much of the basic work on this technique has been done in horses; results have shown increased tissue volume and an increased amount of type II collagen in the reparative tissue.

- **Dr. Allan Gross, Professor of Surgery, University of Toronto, Canada**

Dr. Gross, the pioneer in large *osteochondral allografts*, explained how surgeons needed to obtain fresh allografts from a tissue bank rather than using processed tissue. The risk of HIV in allografts is 1 in 500,000. A high rate of success is possible by simply converting to a total knee arthroplasty if osteochondral grafts fail.

- **Dr. Vladimir Bobic, Consultant Knee Surgeon, Chester, United Kingdom**

Dr. Bobic is one of the initiators of the osteochondral autograft technique called the *OATS procedure*, as well as the use of multiple small plugs to create a "mosaicplasty." He spoke on the indications and contraindications of the OATS procedure. He felt that the best lesions to treat were small, 10- to 15-mm-diameter lesions with partial-thickness articular cartilage loss; larger lesions had a much higher failure rate. The correct surgical technique is most important, and the articular surface of the transplanted articular cartilage must be flush with the adjacent articular surface.

If the graft subsides (or sinks in), the result is no better than no treatment whatsoever. Sometimes the bony part of the graft incorporates into the patient's bone, but the articular cartilage is poorly integrated into the adjacent normal cartilage, which also creates problems.

► **Dr. Lars Peterson, Professor of Orthopaedics, Gothenburg, Sweden**

Dr. Peterson spoke on *autologous chondrocyte implantation* (ACI) or transplantation. He uses this procedure for cases with 1 to 16 cm² of articular cartilage loss with a relatively intact or undamaged opposing articular surface. The technique involves harvesting articular cartilage and growing the chondrocytes in tissue culture to 10 times the volume of cells. The cells are then implanted beneath a periosteal envelope, covering the defect, and sutured to the normal cartilage surface. Good to excellent results are seen in 84% of cases, and follow-up studies with biopsies have shown a large percentage of type II collagen in the repaired tissue.

Many concomitant procedures can be done with the ACI technique, including anterior cruciate ligament reconstruction, high tibial osteotomies, or stabilization of the patellofemoral joint. Meniscal allografts can also be inserted and, if there is a very deep lesion, Dr. Peterson uses bone graft in the base of the defect and the chondral autograft cells on top. He calls this the “sandwich technique.”

Major problems with the technique are fibrillation, in which the periosteal patches separate from the underlying grafted cartilage cells, and delamination, in which the new tissues do not stick to the deep layers. Sometimes synovium overgrows the area and produces a sensitive region.

SESSION 5—REALIGNMENT TECHNIQUES

► **Dr. Allan Gross, Professor of Surgery, University of Toronto, Canada**

Dr. Gross discussed the advantages of a distal femoral osteotomy using the *medial closing wedge technique* for a valgus knee. He stated that a distal femoral osteotomy was essential in aligning a leg when there was a superolateral tilt to the joint line, and that the closing femoral wedge from the medial side would make the joint line horizontal to the long axis of the leg. It is necessary to have long x-rays to show the head of the femur, the knee, and the ankle in order to get the appropriate mechanical alignment, which should be the weightbearing alignment and not the anatomical alignment. A similar procedure can be done on the tibia for a varus deformity by using the traditional lateral closing wedge tibial osteotomy.

► **Dr. Giancarlo Puddu, Orthopaedic Surgeon, Rome, Italy**

Dr. Puddu described tibial and femoral osteotomies using an *opening wedge technique*. Through a small incision on the medial side of the tibia, a saw cut through the tibial metaphysis is made and directed obliquely upward toward the superolateral corner of the tibia. Into this cut are inserted 2 units, which when joined together form a “jack” to open the wedge. When appropriate longitudinal correction has been obtained, a “spacer tooth” of the appropriate size is inserted, followed by bone graft—either allograft bone or graft obtained locally or from the iliac crest. The “tooth” is screwed to the bone and holds it open, allowing the patient to move with restricted weightbearing until union has occurred. A similar procedure can be done on the lower end of the femur, from the lateral side.

► **Dr. Paul Freudigman, Director of Orthopaedic Trauma, Baylor University Medical Center, Dallas, Texas**

Dr. Freudigman is one of North America’s leading experts on the *Ilizarov technique*. The Ilizarov alignment apparatus gradually corrects deformities, with osteoclasis of the long bone and minimal disruption of the periosteum. This enables “dynamic adjustable alignment” and customization of the treatment. It is essential to determine the site of the deformity in order to choose the point of correction. Circular rings applied to the limb are held in place by percutaneous transfixing pins. The osteotomy is created, and then the rings are slowly adjusted, exterior to the limb, to obtain the correction.

► **Dr. Charles Sorbie, Professor of Surgery, Queen’s University, Kingston, Canada**

Dr. Sorbie spoke about *alignment techniques*, describing an accurate method developed at Queen’s University, Kingston, Ontario, for obtaining the appropriate x-rays for joint alignment, both for preoperative planning and postoperative evaluation.

SESSION 6—REPLACEMENT ARTHROPLASTY

► **Dr. Robert W. Jackson, Chief of Orthopaedic Surgery, Baylor University Medical Center, Dallas, Texas**

Dr. Jackson provided some interesting history on *unicompartmental arthroplasty*, noting that the initial unicompartmental arthroplasty was done by Dr. David L. MacIntosh in the early 1950s. Dr. MacIntosh found degenerative changes localized to the medial compartment of a woman’s knee and replaced the surface with a plastic mold of the upper end of the tibia that had been given to him by a colleague. It worked well, and he developed metal implants of different thicknesses and sizes and the concept of “shimming open” the arthritic medial compartment by increasing the size of each implant until alignment had been achieved. Dr. Leonard Marmor independently developed a metal femoral component that articulated with a polyethylene tibial component. Early on, the success rate of many of the subsequent types of unicompartmental arthroplasties was unpredictable, as indications for the technique were not fully developed. However, recent studies have shown that unicompartmental knee arthroplasties can be successful in 92% of cases at an average of 4 years, and the Oxford unicompartmental knee has received excellent reviews at 10 years with a 97% survival rate. Problems that can occur include collapse of the medial plateau, dislocation, and, in cases of overcorrection, stress fractures of the compaction type in the other compartment of the knee. Lateral unicompartmental knee arthroplasties have a fairly high failure rate. The success of most of the procedures is believed to be due to the retention of proprioception in the lateral and patellofemoral compartments, plus the realignment or balancing of the leg.

► **Dr. Marc Friedman, Assistant Professor, University of California, Los Angeles, California**

Dr. Friedman discussed the *Unispacer*, which is essentially a redesign of the old MacIntosh hemiarthroplasty. Use of the Unispacer involves a very high learning curve, and early studies showed as much as 8% to 10% dislocation of the implant. In his own experience, Dr. Friedman had a 23% revision rate. He noted that the patient’s symptomatic improvement might take 3 to 6

months. There was no immediate relief, and even in the best of cases, the pain relief was usually only 80%.

► **Dr. Scott Gillogly, Orthopaedic Surgeon, Atlanta Sports Medicine and Orthopaedic Center, Atlanta, Georgia**

Dr. Gillogly discussed the minimally invasive *Repicci arthroplasty technique*, in which power tools are used to shape both the femoral and tibial sides, and the implants are inserted. The technique is considered best for older patients, and the results can be quite dramatic. If there is insufficient relief of pain and improvement in function, the cases can be converted into total joint arthroplasties without difficulty.

Although there is a relatively low morbidity rate, the technique of insertion has to be learned. The polyethylene on the tibial side is inlaid, with a rim of bone surrounding it. It is important to preserve the sclerotic base of the tibial compartment, because if one breaks through into the cancellous bone of the metaphysis, there could be subsidence of the tibial inlay. His indications for a Repicci are severe medial pain in the 50- to 80-year age group. Range of motion should be at least 10° to 90°, and there should be <10° of varus. In Repicci's own series, 85% of patients were satisfied, but there was a 23% revision rate in cases of severe osteoarthritis.

► **Dr. Robert Bourne, Professor of Surgery, University of Western Ontario, London, Canada**

Dr. Bourne discussed *total knee arthroplasty* in one of the best presentations of the meeting. There is no question that total knee replacement has revolutionized the treatment of the arthritic knee in its late stages. However, some controversies still exist. For example, should the posterior cruciate ligament be sacrificed and, if so, what are the results? It is certainly easier to put in a total knee with a sacrificed posterior cruciate, and in some reported series, the results are better. It is probably necessary to sacrifice the posterior cruciate ligament if the deformity is >15° of fixed flexion.

Fluoroscopic studies have shown that the lateral compartment rotates as the knee is brought into full extension. But clinical studies have shown no significant need for a rotating bearing. The mobile bearing total knee replacements consist of 2 types: either the polyethylene moves or the rotating platform moves. While a mobile bearing does decrease contact stresses on the superior surface, it also causes wear on both sides of the polyethylene implant, and a loose rotating unit is prone to dislocation. There is also more volumetric wear in both cases.

The question of patella resurfacing was addressed. The early designs of knee replacements that did not include the patella showed a high incidence of anterior knee pain. Anterior knee pain is, of course, multifactorial and is well described in a 2003 review article in the *Journal of Bone and Joint Surgery*. However, implant design has been improved and now, according to the Swedish registry, there appears to be no significant difference in knees with resurfaced or nonresurfaced patellae. Randomized trials are currently being carried out. A metaanalysis of published studies has shown that patient satisfaction is quite similar in these 2 groups. In Dr. Bourne's opinion, if the patient is <60 years, the patella should not be replaced. If the patient is >60 years, the patella should be replaced with a patient-friendly implant. It is

also well known that metal-backed patellas have a tendency to fail very quickly.

Dr. Bourne also discussed XLPE, which is the cross-linked polyethylene material that is currently being advocated. He suggested a cautious approach toward this material and stressed the need for registries such as the Canadian Hip and Knee Registry, which can establish rates of revision and success and also influence governmental policy.

► **Dr. Allan Gross, Professor of Surgery, University of Toronto, Canada**

Dr. Gross discussed *revision arthroplasty*. He stressed establishing, in each case, whether the defect to be corrected is an uncontained defect and whether it is primarily on the femoral or tibial side. Numerous modular implants and bone grafts (either allografts or autografts) are necessary. "Mega-modular" implants are also on the market now and are similar to those that are used in tumor replacement therapy.

► **Dr. Sumant Krishnan, Assistant Clinical Professor, The University of Texas Southwestern Medical Center and Baylor University Medical Center, Dallas, Texas**

Dr. Krishnan gave a superb overview of *venous thromboembolic prophylaxis*. Often asymptomatic deep vein thromboses (DVTs) are not suspected. After knee replacement, the diagnosis of symptomatic DVT is made an average of 17 days postoperatively. A venographically proven DVT occurs in 28% to 47% of patients after knee replacement. Even if it is not fatal, it can cause post-thrombotic syndrome, a chronic disfiguring and potentially disabling condition involving pain, edema, skin induration, and late-stage ulceration. A reported 24% of patients with previous asymptomatic postoperative DVT develop the postthrombotic syndrome in 2 to 4 years.

Prevention is better than treatment. Mechanical prophylaxis through pneumatic compression boots has been quite effective, with only a 4.6% instance of postoperative DVT. Patient compliance is important, as is early ambulation and exercise, even in bed. Chemical prophylaxis, the mainstay of preventive treatment for many years, has the disadvantages of bleeding, risk of allergies, and inhibition of thrombin and factor XA; it also requires monitoring. Warfarin and low-molecular-weight heparin have been used quite extensively. More recently, fondaparinux, which binds specifically to antithrombin, is useful as once-daily subcutaneous dosing. Dr. Krishnan's final recommendation was to combine mechanical and chemical agents to get maximum prevention, although the length of time that such prophylaxis is necessary is still unknown. Most surgeons feel that when the patient is out of bed most of the day and actively using his muscles, the prophylactic regime can be discontinued.

► **Dr. Paul Freudigman, Director of Orthopaedic Trauma, Baylor University Medical Center, Dallas, Texas**

Dr. Freudigman discussed the *salvage of the septic knee*. He stressed that prevention of sepsis is always better than treatment. In some instances, the infected prosthesis can be retained by aggressively using an irrigation and drainage system along with antibiotics. However, replacement of the unit is usually necessary, and there is controversy as to whether this should be

done in 1 or 2 stages. Dr. Freudigman felt that the 2-stage situation was better; he generally removes the prosthesis, puts in a polymethacrylate spacer containing antibiotic, and at a second operation 6 weeks later installs a second prosthesis. Other salvage procedures included resection arthroplasty, arthrodesis, and even amputation.

SESSION 7—WHAT'S IN THE FUTURE?

► *Dr. Wayne Marshall, Assistant Professor of Surgery, University of Toronto, Canada*

Dr. Marshall described the ongoing efforts to study the *genome factors* in many conditions, particularly osteoarthritis. Common genetic markers have been identified, and the presence of biomarkers will soon enable physicians to identify patients at risk of arthritis.

► *Dr. Fabian Pollo, Biomedical Engineer, Director of Orthopaedic Research, Baylor University Medical Center, Dallas, Texas*

Dr. Pollo talked about *tissue welding techniques* that have been developed at Baylor to bond or weld collagenous tissues using photoactive naphthalimide compounds. These compounds, when activated by light at a specific wavelength, can bond to adjacent collagenous structures and produce a biological weld of the tissues. This differs from “glue,” which is an interpositional substance that sticks to both sides. The initial studies have been performed on sheep but not on humans. Methods of assessing the bonding strength are being developed, as are new and better chemical compounds.

► *Dr. Gonzalo Vazquez-Vela, Chief of Orthopaedics, Hospital Angeles del Pedregal, Mexico City, Mexico*

Dr. Vazquez-Vela has been part of a 2-country (Norway and Mexico) clinical study to produce a *polymer implant*. The arthritic compartment is prepared by arthroscopic means, and a polymer is injected, which sets up in 1½ minutes. This produces a smooth surface. The first polymer to be tested failed due to breakdown, as it was unable to withstand the stresses of activity. Those operations were easily converted to total knee replacements. The research is now into its fourth phase, using improved polymers, but for proprietary reasons, the data could not be released. It was an interesting concept, suggesting that someday resurfacing arthroplasties could be done endoscopically.

► *Dr. Charles Sorbie, Professor of Surgery, Queen's University, Kingston, Canada*

Dr. Sorbie spoke on *polyethylene* and described its history, chemistry, and methods of production, as well as how it has been made stronger and more resistant to wear.

SPECIAL LECTURES

► *Dr. McCollister Evarts, Dean Emeritus, Faculty of Medicine, Pennsylvania University, Hershey, Pennsylvania*

Dr. Evarts addressed the topic of *orthopaedics in the 21st century*. He was a practicing orthopaedic surgeon for many years before becoming chairman of the Department of Orthopaedics at Rochester and then dean of the medical school at Hershey, Pennsylvania. Consequently, his experience in analyzing the

factors that are at play in orthopaedics is invaluable. One of the advances in recent years has been better communication between orthopaedics and other disciplines of science, such as biomechanics, autoimmunity, biotechnology, genetics, protein chemistry, and imaging—these are called cross-cutting communications. This improved communication has led to major advances over the past few years in joint reconstruction, arthroscopic surgery, and the treatment of thromboembolic disease. Further good work is being done on cartilage repair and on bone biology, including osteoporosis and fractures.

The health care environment has changed from fee-for-service to managed care insurance plans and multihospital systems. Health care is now a \$150 billion a year business, and there is a significant struggle between the ethical practices of traditional doctors and the insurance companies. This is leading to an erosion of patients' trust. In the past, physicians advocated for patients, with the sole goal of providing optimal care. With the current marketplace, physicians have become mere proxies for the insurance plans and are obliged to give low-cost care. The impact of these changes has resulted in a real threat to academic medicine. Patient-doctor relationships are seriously affected, and good biomedical research is at risk due to decreasing revenues from the clinical enterprise. We are now entering an era of unmanaged competition.

Dr. Evarts noted that we have failed to take full advantage of possible interdepartmental collaboration in the academic arena, and the market-driven health care system has no incentive to support medical education. He stated that mergers and acquisitions of hospitals and leasing of facilities have essentially been failed strategies in attempting to manage dwindling hospital resources. Moreover, the Balanced Budget Act of 1997 has seriously affected the ability of a hospital to provide medical care for poor people.

Dr. Evarts recommended that orthopaedists avoid becoming technocrats in fields such as arthroscopic surgery, fracture repair, physiotherapy, and imaging. He also advised orthopaedists to avoid fragmentation; they should be generalists first and then subspecialists. He concluded that in the world of science, orthopaedics has definitely achieved a specialty status. However, it has not yet achieved the status of a discipline, which involves extensive research, publication, and teaching.

► *Dr. Robert Leach, Editor Emeritus, The American Journal of Sports Medicine*

Dr. Leach addressed the subject of the *aging athlete*. He briefly reviewed the local changes that occur in connective tissues, tendons, and menisci in the knee, as well as the neurological, pulmonary, and cardiac problems that symptomatically affect the aging athlete. The only thing that aging athletes never lose is experience; however, their physical strength, reflexes, and endurance all deteriorate with the passage of time.

In a second address, Dr. Leach discussed *living with an arthritic knee*. He described 6 entities necessary to preserve function for as long as possible: 1) lifestyle changes, 2) exercise and physical therapy, 3) medications, 4) braces and other aids, 5) yearly follow-up, and 6) further operations.